TABLE 1. Mortality and Morbidity Risk Coefficients for Selected Radionuclides[a]

Isotope	Lifetime Cancer Risk					
	Mortality			Morbidity		
	Inhalation	Ingestion	External	Inhalation	Ingestion	External
Americium-241	2.4×10^{-8}	9.5×10^{-11}	1.9×10^{-8}	2.8×10^{-8}	1.3×10^{-10}	2.8×10^{-8}
Americium-242m	1.3×10^{-8}	6.8×10^{-11}	-	1.6×10^{-8}	9.0×10^{-11}	-
Americium-243	2.3×10^{-8}	9.8×10^{-11}	4.3×10^{-7}	2.7×10^{-8}	1.4×10^{-10}	6.4×10^{-7}
Berkelium-247	4.0×10^{-8}	1.2×10^{-10}	2.1×10^{-7}	4.8×10^{-8}	1.6×10^{-10}	3.1×10^{-7}
Cadmium-109	2.0×10^{-11}	4.2×10^{-12}	-	2.2×10^{-11}	6.7×10^{-12}	-
Cadmium-113	8.1×10^{-11}	2.0×10^{-11}	-	1.1×10^{-10}	2.9×10^{-11}	-
Cadmium-113m	9.3×10^{-11}	2.5×10^{-11}	-	1.3×10^{-10}	3.6×10^{-11}	-
Californium-248	2.4×10^{-8}	3.8×10^{-11}	-	2.6×10^{-8}	6.2×10^{-11}	-
Californium-249	4.0×10^{-8}	1.2×10^{-10}	9.3×10^{-7}	4.8×10^{-8}	1.6×10^{-10}	1.4×10^{-6}
Californium-250	3.5×10^{-8}	8.0×10^{-11}	-	3.7×10^{-8}	1.1×10^{-10}	-
Californium-251	4.1×10^{-8}	1.3×10^{-10}	2.6×10^{-7}	4.9×10^{-8}	1.7×10^{-10}	3.8×10^{-7}
Californium-252[b]	2.1×10^{-8}	4.1×10^{-11}	-	2.2×10^{-8}	5.7×10^{-11}	-
Carbon-14	6.5×10^{-12}	1.4×10^{-12}	-	7.1×10^{-12}	2.0×10^{-12}	-
Cesium-134	1.1×10^{-11}	3.5×10^{-11}	4.8×10^{-6}	1.6×10^{-11}	5.1×10^{-11}	7.1×10^{-6}
Cesium-135	1.3×10^{-12}	4.0×10^{-12}	-	1.9×10^{-12}	5.9×10^{-12}	-
Cesium-137	8.1×10^{-12}	2.5×10^{-11}	1.7×10^{-6}	1.2×10^{-11}	3.7×10^{-11}	2.5×10^{-6}
Chlorine-36	9.6×10^{-11}	2.9×10^{-12}	-	1.0×10^{-10}	4.4×10^{-12}	-
Cobalt-57	1.8×10^{-12}	9.0×10^{-13}	2.4×10^{-7}	2.1×10^{-12}	1.5×10^{-12}	3.6×10^{-7}
Cobalt-60	3.0×10^{-11}	1.4×10^{-11}	8.5×10^{-6}	3.6×10^{-11}	2.2×10^{-11}	1.2×10^{-5}
Curium-242	1.4×10^{-8}	3.2×10^{-11}	-	1.5×10^{-8}	5.5×10^{-11}	-
Curium-243	2.4×10^{-8}	8.5×10^{-11}	2.9×10^{-7}	2.7×10^{-8}	1.2×10^{-10}	4.2×10^{-7}
Curium-244	2.3×10^{-8}	7.5×10^{-11}	-	2.5×10^{-8}	1.1×10^{-10}	-
Curium-245	2.4×10^{-8}	9.5×10^{-11}	1.6×10^{-7}	2.8×10^{-8}	1.3×10^{-10}	2.4×10^{-7}
Curium-246	2.4×10^{-8}	9.3×10^{-11}	-	2.8×10^{-8}	1.3×10^{-10}	-
Curium-247	2.2×10^{-8}	9.1×10^{-11}	9.3×10^{-7}	2.5×10^{-8}	1.3×10^{-10}	1.4×10^{-6}
Curium-248[c]	8.8×10^{-8}	3.4×10^{-10}	-	1.0×10^{-7}	4.8×10^{-10}	-
Curium-250[c]	5.0×10^{-7}	2.0×10^{-9}	9.7×10^{-7}	5.8×10^{-7}	2.8×10^{-9}	1.4×10^{-6}
Europium-150	2.1×10^{-10}	3.6×10^{-12}	4.4×10^{-6}	2.6×10^{-10}	6.1×10^{-12}	6.5×10^{-6}
Europium-152	1.5×10^{-10}	5.0×10^{-12}	3.6×10^{-6}	1.9×10^{-10}	8.7×10^{-12}	5.3×10^{-6}
Europium-154	1.7×10^{-10}	8.5×10^{-12}	4.0×10^{-6}	2.1×10^{-10}	1.5×10^{-11}	5.8×10^{-6}
Europium-155	1.7×10^{-11}	1.6×10^{-12}	8.4×10^{-8}	1.9×10^{-11}	2.8×10^{-12}	1.2×10^{-7}
Iodine-129	6.2×10^{-12}	2.0×10^{-11}	-	6.1×10^{-11}	1.9×10^{-10}	-
Iodine-131	2.1×10^{-12}	6.9×10^{-12}	1.1×10^{-6}	1.9×10^{-11}	6.5×10^{-11}	1.6×10^{-6}
Iridium-192	2.1×10^{-11}	6.0×10^{-12}	2.3×10^{-6}	2.4×10^{-11}	1.1×10^{-11}	3.4×10^{-6}
Iridium-192m	1.7×10^{-11}	8.7×10^{-13}	3.7×10^{-7}	2.0×10^{-11}	1.3×10^{-12}	5.4×10^{-7}
Iridium-194m	4.0×10^{-11}	7.3×10^{-12}	6.9×10^{-6}	4.6×10^{-11}	1.3×10^{-11}	1.0×10^{-5}
Neptunium-235	1.0×10^{-12}	2.8×10^{-13}	-	1.2×10^{-12}	5.1×10^{-13}	-
Neptunium-236	2.6×10^{-9}	1.5×10^{-11}	2.2×10^{-7}	3.0×10^{-9}	2.3×10^{-11}	3.2×10^{-7}
Neptunium-237	1.5×10^{-8}	5.8×10^{-11}	5.4×10^{-7}	1.8×10^{-8}	9.1×10^{-11}	8.0×10^{-7}
Nickel-59	3.6×10^{-13}	2.3×10^{-13}	-	4.7×10^{-13}	3.9×10^{-13}	-
Nickel-63	1.4×10^{-12}	5.7×10^{-13}	-	1.6×10^{-12}	9.5×10^{-13}	-

Isotope	Lifetime Cancer Risk					
	Mortality			Morbidity		
	Inhalation	Ingestion	External	Inhalation	Ingestion	External
Plutonium-236	2.1×10^{-8}	6.9×10^{-11}	-	2.3×10^{-8}	9.9×10^{-11}	-
Plutonium-238	3.0×10^{-8}	1.3×10^{-10}	-	3.4×10^{-8}	1.7×10^{-10}	-
Plutonium-239	2.9×10^{-8}	1.3×10^{-10}	-	3.3×10^{-8}	1.7×10^{-10}	-
Plutonium-240	2.9×10^{-8}	1.3×10^{-10}	-	3.3×10^{-8}	1.7×10^{-10}	-
Plutonium-241	2.8×10^{-10}	1.9×10^{-12}	-	3.3×10^{-10}	2.3×10^{-12}	-
Plutonium-242	2.8×10^{-8}	1.3×10^{-10}	-	3.1×10^{-8}	1.7×10^{-10}	-
Plutonium-244[d]	2.7×10^{-8}	1.3×10^{-10}	1.0×10^{-6}	3.1×10^{-8}	1.6×10^{-10}	1.5×10^{-6}
Polonium-210	1.0×10^{-8}	1.6×10^{-9}	-	1.1×10^{-8}	2.3×10^{-9}	-
Potassium-40	2.1×10^{-10}	2.2×10^{-11}	5.5×10^{-7}	2.2×10^{-10}	3.4×10^{-11}	8.0×10^{-7}
Protactinium-231	2.5×10^{-7}	6.0×10^{-10}	1.1×10^{-6}	2.6×10^{-7}	8.8×10^{-10}	1.6×10^{-6}
Radium-226	2.4×10^{-8}	2.9×10^{-9}	5.8×10^{-6}	2.5×10^{-8}	4.0×10^{-9}	8.5×10^{-6}
Radium-228	9.0×10^{-8}	1.3×10^{-9}	8.4×10^{-6}	9.7×10^{-8}	1.9×10^{-9}	1.2×10^{-5}
Samarium-146	1.2×10^{-8}	4.0×10^{-11}	-	1.4×10^{-8}	5.3×10^{-11}	-
Samarium-151	8.6×10^{-12}	4.6×10^{-13}	-	9.2×10^{-12}	8.1×10^{-13}	-
Selenium-79	2.3×10^{-12}	6.7×10^{-12}	-	3.3×10^{-12}	9.7×10^{-12}	-
Strontium-90	1.0×10^{-10}	7.5×10^{-11}	-	1.1×10^{-10}	9.5×10^{-11}	-
Technetium-97	7.6×10^{-13}	2.3×10^{-13}	-	8.5×10^{-13}	3.9×10^{-13}	-
Technetium-98	2.6×10^{-11}	6.0×10^{-12}	4.4×10^{-6}	3.0×10^{-11}	1.0×10^{-11}	6.5×10^{-6}
Technetium-99	1.3×10^{-11}	2.3×10^{-12}	-	1.4×10^{-11}	4.0×10^{-12}	-
Thorium-229	2.2×10^{-7}	4.7×10^{-10}	7.8×10^{-7}	2.3×10^{-7}	7.2×10^{-10}	1.2×10^{-6}
Thorium-230	2.7×10^{-8}	8.0×10^{-11}	-	2.9×10^{-8}	1.2×10^{-10}	-
Thorium-232	4.1×10^{-8}	9.1×10^{-11}	-	4.3×10^{-8}	1.3×10^{-10}	-
Tin-121m	4.1×10^{-11}	2.9×10^{-12}	-	4.4×10^{-11}	5.1×10^{-12}	-
Tin-126	3.9×10^{-10}	3.0×10^{-11}	8.8×10^{-6}	4.2×10^{-10}	5.3×10^{-11}	1.3×10^{-5}
Tritium (H-3)	3.9×10^{-14}	4.4×10^{-14}	-	5.6×10^{-14}	6.5×10^{-14}	-
Uranium-232	1.8×10^{-8}	2.7×10^{-10}	-	1.9×10^{-8}	3.9×10^{-10}	-
Uranium-233	1.1×10^{-8}	6.3×10^{-11}	-	1.2×10^{-8}	9.7×10^{-11}	-
Uranium-234	1.1×10^{-8}	6.1×10^{-11}	-	1.1×10^{-8}	9.5×10^{-11}	-
Uranium-235	9.5×10^{-9}	6.2×10^{-11}	3.7×10^{-7}	1.0×10^{-8}	9.8×10^{-11}	5.4×10^{-7}
Uranium-236	9.9×10^{-9}	5.8×10^{-11}	-	1.0×10^{-8}	9.0×10^{-11}	-
Uranium-238	8.8×10^{-9}	7.5×10^{-11}	-	9.3×10^{-9}	1.2×10^{-10}	-
Zirconium-93	8.4×10^{-12}	1.7×10^{-12}	-	9.2×10^{-12}	2.6×10^{-12}	-

[a] This table provides selected risk coefficients for inhalation and dietary ingestion of various radionuclides, and for external gamma irradiation where that entry is appropriate. (Source: *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report 13, U.S. Environmental Protection Agency, EPA 402-R-99-001, September 1999.) The mortality risk represents the lifetime risk of incurring a fatal cancer, and the morbidity risk represents the risk of incurring all cancers (fatal and non-fatal). Values are averaged over all ages and both genders. (For context, 10^{-9} is a billionth, 10^{-12} is a trillionth, and a pCi is a picocurie, or a trillionth of a curie.) To convert to standard international units, multiply by 27 pCi per becquerel (Bq). Values shown here include the contributions from short-lived decay products, as indicated in the radionuclide-specific fact sheets. (For example, strontium-90 includes the contribution from yttrium-90, and uranium-238 includes the contribution from thorium-234).

For ingestion and inhalation, units are risk per pCi. For inhalation, the values corresponding to the recommended default absorption type for particulates are shown; the maximum value is given if no absorption type was

recommended. For ingestion, the dietary values shown are the highest for ingestion exposures; values for tap water ingestion are typically 70 to 80% of those for diet. The values for tritium are for tritiated water.

For external exposure, risk coefficients are given for those radionuclides having gamma-ray energies in excess of 0.03 MeV per decay, accounting for the fraction of time that the radioactive decay results in the emission of gamma rays. A dash indicates the radionuclide or its decay products does not emit significant gamma radiation *(*see the companion fact sheet on *Radioactive Properties, Internal Distribution, and Risk Coefficients).* Units for external gamma risk coefficients shown in the table are risk per pCi/g soil for one year of exposure. Although no inhalation or ingestion coefficients are available for krypton isotopes, coefficients do exist for external gamma exposures. Submersion in a cloud of krypton gas poses the highest risk, and the following values are in units of risk per pCi/cm^3 air for one year of exposure. For krypton-81, mortality and morbidity risk coefficients are 1.5×10^{-5} and 2.3×10^{-5}, respectively. For krypton-85, mortality and morbidity risk coefficients are 8.5×10^{-6} and 1.2×10^{-5}, respectively.

[b] Standard risk coefficients are not available for californium-252. To help address this gap, values shown here have been derived by multiplying the standard risk coefficients for californium-250 by the ratios of the dose conversion factors for californium-252 to californium-250, for the given exposure pathways and endpoints.

[c] Standard risk coefficients are not available for curium-248 or curium-250. To help address this gap, values shown here have been derived. For curium-248, standard risk coefficients for curium-246 were multiplied by the ratios of the standard dose conversion factors for curium-248 to curium-246, for the given exposure pathways and endpoints. For curium-250, standard risk coefficients for curium-246 were multiplied by the ratios of the standard dose conversion factors for curium-250 to curium-246, for the given exposure pathways and endpoints. The risk coefficient for external exposure for curium-250 is attributable to its short-lived radioactive decay products.

[d] Standard risk coefficients are not available for plutonium-244. To help address this gap, values shown here have been derived by multiplying the standard risk coefficients for plutonium-242 by the ratios of the dose conversion factors for plutonium-244 to plutonium-242, for the given exposure pathways and endpoints. The risk coefficient for external exposure is attributable to its short-lived radioactive decay products, principally neptunium-240m.